

## DAY TWENTY

# Hydrogen

### Learning & Revision for the Day

- |  |                                  |  |
|--|----------------------------------|--|
| ♦ Position of Hydrogen in Periodic Table | ♦ Dihydrogen                     | ♦ Hard and Soft water                          |
| ♦ Isotopes of Hydrogen                   | ♦ Hydrides                       | ♦ Hydrogen Peroxide ( $\text{H}_2\text{O}_2$ ) |
|  | ♦ Water ( $\text{H}_2\text{O}$ ) |  |

Dihydrogen ( $\text{H}_2$ ) is the most abundant element in the universe (70% of the total mass of the universe) and is the principal element in the solar atmosphere. The giant planets Jupiter and Saturn consist of mainly hydrogen. It is the lightest element known.

## Position of Hydrogen in Periodic Table

The position of hydrogen in periodic table is uncertain as it shows resemblance with alkali metals as well as with halogens. However, on the basis of electronic configuration ( $1s^1$ ), it is placed above lithium in the periodic table but still, it is not considered as the member of that group. On the other hand, like halogens (with  $ns^2, np^5$  configuration), it is short by one electron to the corresponding noble gas configuration but it is still not considered as the member of seventeenth group. Thus, it has unique behaviour and is therefore best placed separately in the periodic table.

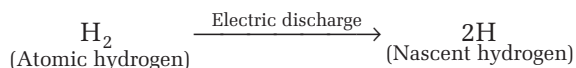
## Isotopes of Hydrogen

- Hydrogen has three isotopes, i.e. protium ( ${}^1_1\text{H}$ ), deuterium or heavy hydrogen ( ${}^2_1\text{H}$  or D) and tritium ( ${}^3_1\text{H}$  or T). Out of these isotopes, only tritium is radioactive and emits low energy  $\beta^-$  particles.
- The three isotopes have different masses and different enthalpy of bond dissociation hence, their rates of reaction and equilibrium constants are different. This is known as **isotopic effect**. They have same electronic configuration and chemical properties.

**NOTE** Allotropes of hydrogen are *ortho*-hydrogen (*o*- $\text{H}_2$ ) (in which proton spin is in same direction) and *para*-hydrogen (*p*- $\text{H}_2$ ) (in which proton spin is in opposite direction). Similarly, deuterium and tritium also exhibit spin isomerism and exist in *ortho*-and *para*-forms.

## Atomic Hydrogen

Hydrogen gas dissociates into atoms when it is subjected to an electric discharge under low pressure.



Atomic hydrogen is very reactive and can be used as a reducing agent as well as oxidising agent.

Reducing power of atomic hydrogen is more than that of nascent hydrogen.

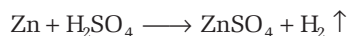
## Dihydrogen

It is the principal element in the solar atmosphere. In the combined form, it occurs in plant and animal tissues.

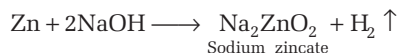
## Preparation of Dihydrogen

Laboratory preparation of dihydrogen are as follows :

- (i) It is prepared by the action of dilute hydrochloric acid on metals that are more reactive than hydrogen granulated zinc, iron, magnesium, etc.

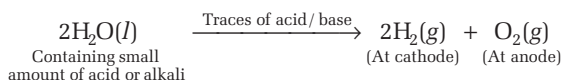


- (ii) Certain metals like Zn, Sn, Al etc., react with NaOH to liberate  $\text{H}_2$

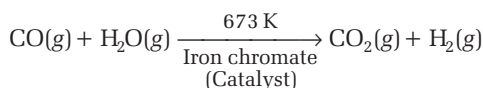
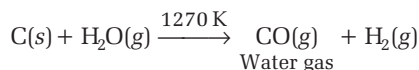


Commercially used processes for the preparation of dihydrogen are as:

- Electrolysis of acidified water using platinum electrodes give dihydrogen.

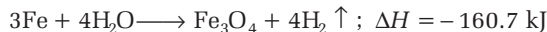


- Dihydrogen of high purity (> 99.95%) is obtained by electrolysis of warm aqueous barium hydroxide solution between nickel electrodes.
- The mixture of CO and  $\text{H}_2$  is called **water gas**. As this mixture is used for the synthesis of methanol and a number of hydrocarbons, it is also called **synthesis gas** or **syn gas**. Now-a-days, 'syn gas' is produced from sewage, scrap wood, newspapers etc. The process of producing 'syn gas' from coal is called coal gasification. (Bosch process)



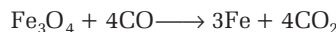
$\text{CO}_2$  is removed by passing the mixture through water at very high pressure. ( $\text{CO}_2$  is dissolved completely in water). This reaction is known as water-gas shift reaction (WGSR)

- Lane's process** involves decomposition of steam over heated Fe ( $550^\circ - 800^\circ\text{C}$ ). This reaction is known as **gassing reaction**.



By the action of water gas,  $\text{Fe}_3\text{O}_4$  is again reduced to iron.

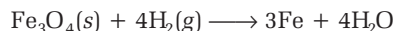
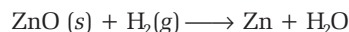
This process is known as **vivification**.



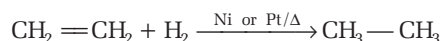
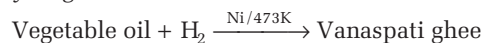
- Dihydrogen is obtained as a byproduct of brine electrolysis process for the manufacturing of NaOH, petroleum cracking plants and many electrolytic reactions.

## Properties of Hydrogen

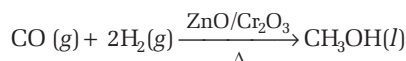
- Hydrogen is colourless, tasteless, odourless gas. It is lightest and slightly soluble in water.
- It is a neutral and highly combustible gas, so in the presence of air, it burns with pale blue flame to form water.
- Reducing action** Hydrogen reduces the oxides of less electropositive elements but cannot reduce the oxides of alkali metals and alkaline earth metals.



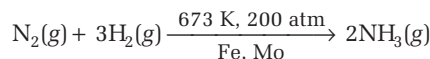
- Hydrogenation



- Reaction with CO



- With dinitrogen, it forms ammonia (Haber's process).



## Uses of Hydrogen

- In hydrogenation of oils.
- In preparation of synthetic petrol.
- In oxy-hydrogen flame.
- In hydrogen-oxygen fuel cells to produce electricity.
- In a fuel cell, electrical energy is generated by the reaction of  $\text{H}_2$  and  $\text{O}_2$  without evolution of heat (cold combustion).
- Liquid hydrogen is used as rocket fuel.
- As a reducing agent in extraction of metals.

## Hydrides

Dihydrogen, under certain reaction conditions combine with almost all elements except noble gases to form binary compounds, called hydrides.

## Classification of Hydrides

The hydrides are classified into four categories.

### 1. Ionic or Saline or Salt-like Hydrides

- These hydrides are stoichiometric compounds of dihydrogen formed with most of the *s*-block elements which are highly electropositive in character, e.g. LiH, BeH<sub>2</sub> and MgH<sub>2</sub>.
- In fact, BeH<sub>2</sub> and MgH<sub>2</sub> are polymeric in structure. Due to their high reactivity with water, ionic hydrides are used to remove traces of water from organic solvents.

### 2. Covalent or Molecular Hydrides

- Dihydrogen forms molecular compounds with most of the *p*-block elements. Most familiar examples are CH<sub>4</sub>, NH<sub>3</sub>, H<sub>2</sub>O and HF etc.
- Molecular hydrides are further classified, according to the relative number of electrons and bonds in their Lewis structure into following types:
  - (i) **Electron deficient hydrides** have incomplete octet, so behave as Lewis acids, i.e. are electron acceptors. e.g. B<sub>2</sub>H<sub>6</sub>. These hydrides are formed by the elements of group 13.
  - (ii) **Electron precise hydrides** have required number of electrons to write their Lewis structure. These are obtained from elements of group 14 (e.g. CH<sub>4</sub>) which are tetrahedral in geometry.
  - (iii) **Electron rich hydrides** have excess electrons, which are present as lone pairs. Elements of group 15-17 form such type of hydrides. e.g.  $\ddot{\text{N}}\text{H}_3$  (1 lone pair),  $\text{H}_2\ddot{\text{O}}$  (2 lone pairs) and  $\text{HF} \ddot{\text{F}}$  (3 lone pairs).

### 3. Metallic or Non-stoichiometric or Interstitial Hydrides

- These are formed by many *d*-block and *f*-block elements, however the metals of group 7, 8 and 9 do not form hydride (hydride gap).
- These hydrides are mainly formed by
  - (i) transition metals of group 3, 4, 5 of *d*-block
  - (ii) Cr metal from group 6
  - (iii) *f*-block elements, e.g. LaH<sub>2.87</sub>, YbH<sub>2.55</sub> etc.
- Metallic hydrides are non-stoichiometric. They have metallic lattice and hydrogen is present at the interstitial sites. These conduct heat and electricity just like metals except hydrides of Eu and Yb. (EuH<sub>2</sub> and YbH<sub>2</sub> are ionic and stoichiometric)

### 4. Polymeric Hydrides and Complex Hydrides

- Polymeric hydrides are formed by elements having electronegativity in the range 1.4 to 2.0, e.g. (BeH<sub>2</sub>)<sub>n</sub>, (AlH<sub>3</sub>)<sub>n</sub> etc.
- In complex hydrides, H<sup>-</sup> acts as ligand and is attached to central metal atom, e.g. LiAlH<sub>4</sub>, LiBH<sub>4</sub> etc.

## Water (H<sub>2</sub>O)

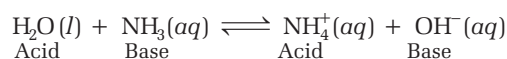
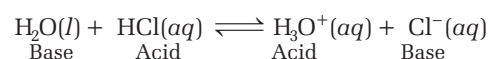
The water molecules contains one oxygen and two hydrogen atoms connected by covalent bonds. The physical and chemical properties of water are given below:

## Physical Properties

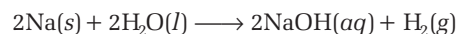
- Water (H<sub>2</sub>O) is polar in nature. It exists in liquid state at room temperature due to intermolecular hydrogen bonding.
- HOH bond angle is 104.5° and O—H bond length is 95.7 pm. H<sub>2</sub>O (ice) has four hydrogen bonds per molecule and hence, has a highly ordered three dimensional cage-like structure.
- Ice has low density than H<sub>2</sub>O (liquid) but H<sub>2</sub>O has maximum density at 3.98°C.

## Chemical Properties

- (i) Water is amphoteric in nature.



- (ii) Water react with metals and non-metals both.



- (iii) In **hydrated salts**, water may remain in five types such as coordinated water, hydrogen bonded water, lattice water, clathrate water and zeolitic water.

- Zeolites** are the hydrated sodium aluminium silicate that contains cavities or certain channels in which H<sub>2</sub>O molecules get trapped.
- Clathrate** contains host molecules that crystallises with an open structure containing water molecules.

- (iv) A number of compounds such as calcium hydride, calcium phosphide etc., undergo hydrolysis with water. The hydrolysis of hydrides with H<sub>2</sub>O is highly exothermic and may be explosive as H<sub>2</sub> catches fire. CO<sub>2</sub> is reduced by hot metal hydride, so it cannot be used to extinguish such fire.

## Hard and Soft Water

The water which lathers with soap is soft, if not, is hard.

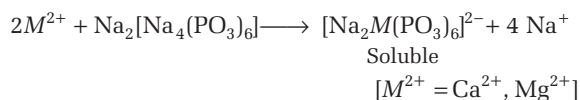
Hardness of water is of two types:

- Temporary Hardness of Water** is due to the presence of magnesium and calcium hydrogen carbonates. It can be removed either by **boiling**, through which the soluble Mg(HCO<sub>3</sub>)<sub>2</sub> is converted into insoluble Mg(OH)<sub>2</sub> and Ca(HCO<sub>3</sub>)<sub>2</sub> is changed into insoluble CaCO<sub>3</sub>. These precipitates can be removed by filtration.
- Permanent Hardness of Water** is due to the presence of soluble salts of magnesium and calcium in the form of chlorides and sulphates.

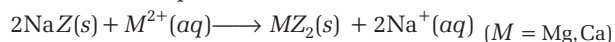
Permanent hardness can be removed by the following methods:

- (i) **Calgon's Method** Sodium hexametaphosphate (Na<sub>6</sub>P<sub>6</sub>O<sub>18</sub>), commercially called calgon, when added to hard water, the calcium and magnesium ions present in hard water react with calgon and form

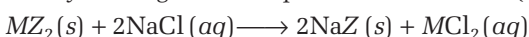
soluble complex salts which does not cause any hinderance in other information.



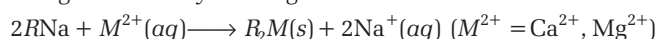
- (ii) **Ion-exchange Method or Permutit or Zeolite process** is also used to remove permanent hardness.



where, NaZ is sodium aluminium silicate ( $NaAlSiO_4$ ). This is also known as sodium zeolite. It is regenerated for further use by treating with an aqueous NaCl solution (brine).



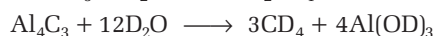
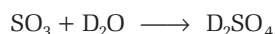
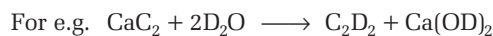
- (iii) **Synthetic Resins Method** Now a days hard water is softened by using synthetic cation exchangers. Cation exchange resins contain large organic molecules with  $-SO_3H$  group and are water insoluble. Ion-exchange resin ( $RSO_3H$ ) is changed to  $RNa$  by treating it with NaCl.



The resin can be regenerated by adding aqueous NaCl solution.

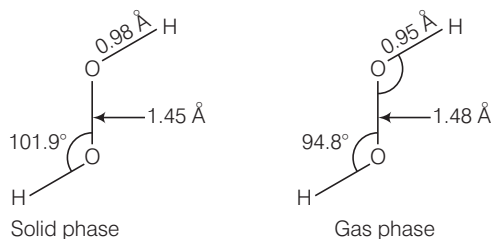
## Heavy Water ( $D_2O$ )

- It has quite similar physical and chemical properties to those of  $H_2O$ . Dielectric constant of  $D_2O$  is lower than that of  $H_2O$  and rate of reactions are much slower than  $H_2O$ .
- It is used as a moderator in nuclear reactions, as trace compound for studying reaction mechanism for the preparation of deuterium.



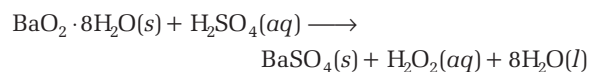
## Hydrogen Peroxide ( $H_2O_2$ )

- Hydrogen peroxide is a compound with an oxygen-oxygen single bond. It is also a strong oxidiser.
- Hydrogen peroxide has a non-polar structure. The molecular dimensions in solid and gas phase are as follows:



## Preparation of $H_2O_2$

- It can be prepared by treating  $BaO_2$  in presence of acid at high temperature.

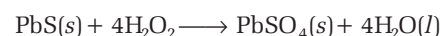
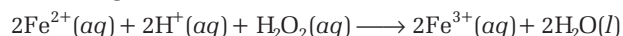


- Industrially, it is prepared by the auto-oxidation of 2-alkylanthraquinols.

## Chemical Properties

- It acts as an oxidising as well as reducing agent in both acidic and alkaline media.

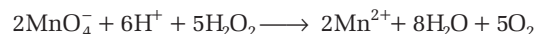
- Oxidising action in acidic medium,



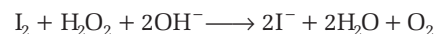
- Oxidising action in basic medium,



- Reducing action in acidic medium,



- Reducing action in basic medium,

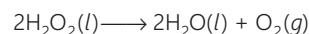


- Many reactions of  $H_2O_2$  are radical reactions, therefore a mixture of  $H_2O_2$  and Fe (II) is a source of hydroxyl radicals for organic reactions.

## Uses of $H_2O_2$

- Aqueous solution of  $H_2O_2$  is used as germicide, antiseptic, preservative for milk and wine, bleaching agent for soft materials. 30%  $H_2O_2$  is called perhydrol. Its volume strength is 100 and molarity is 8.8.
- It is used as an antichlor and in refreshing old oil paintings which became black.

**NOTE**  $H_2O_2$  decomposes slowly on exposure to light,



In the presence of metal surfaces or traces of alkali (present in glass containers), the above reaction is catalysed. It is therefore, stored in wax lined glass or plastic vessels in dark. Urea can be added as a stabiliser.

## DAY PRACTICE SESSION 1

# FOUNDATION QUESTIONS EXERCISE

- 1 *Ortho* and *para* hydrogen differ in the
  - (a) number of protons
  - (b) molecular weight
  - (c) nature of spins of protons
  - (d) nature of spins of electrons
- 2 The metal, which gives hydrogen on treatment with acid as well as sodium hydroxide is
  - (a) Fe
  - (b) Zn
  - (c) Cu
  - (d) None of these
- 3 Which of the following reactions increases production of dihydrogen from synthesis gas?
  - (a)  $\text{CH}_4(g) + \text{H}_2\text{O}(g) \xrightarrow{1270\text{ K}} \text{CO}(g) + 3\text{H}_2(g)$
  - (b)  $\text{C}(s) + \text{H}_2\text{O}(g) \xrightarrow{1270\text{ K, Ni}} \text{CO}(g) + \text{H}_2(g)$
  - (c)  $\text{CO}(g) + \text{H}_2\text{O}(g) \xrightarrow{673\text{ K}} \text{CO}_2(g) + \text{H}_2(g)$
  - (d)  $\text{C}_2\text{H}_6 + 2\text{H}_2\text{O} \xrightarrow[1270\text{ K}]{\text{Catalyst, Ni}} 2\text{CO} + 5\text{H}_2$
- 4 In context with the industrial preparation of hydrogen from water gas ( $\text{CO} + \text{H}_2$ ), which of the following is the correct statement?
  - (a) CO is oxidised to  $\text{CO}_2$  with steam in the presence of catalyst followed by absorption of  $\text{CO}_2$  in alkali
  - (b) CO and  $\text{H}_2$  are fractionally separated using differences in their densities
  - (c) CO is removed by absorption in aqueous  $\text{Cu}_2\text{Cl}_2$  solution
  - (d)  $\text{H}_2$  is removed through occlusion with Pd
- 5  $\text{H}_2$  gas is liberated at anode by electrolysis of which of the following aqueous solution?
  - (a) NaH
  - (b)  $\text{HCOO}^-\text{Na}^+$
  - (c) NaCl
  - (d) LiH
- 6 Very pure hydrogen (99.9) can be made by which of the following processes?
  - (a) Reaction of methane with steam
  - (b) Mixing natural hydrocarbons of high molecular weight
  - (c) Electrolysis of water
  - (d) Reaction of salts like hydrides with water
- 7 In which of the following reactions does dihydrogen act as oxidising agent?
  - (a)  $\text{Ca} + \text{H}_2 \longrightarrow$
  - (b)  $\text{H}_2 + \text{O}_2 \longrightarrow$
  - (c)  $\text{H}_2 + \text{F}_2 \longrightarrow$
  - (d)  $\text{CuO} + \text{H}_2 \longrightarrow$
- 8 The maximum possible number of hydrogen bonds in a water molecule can form in ice is
  - (a) 1
  - (b) 2
  - (c) 3
  - (d) 4
9. Which one is used as propellants for rockets?
  - (a) Liq.  $\text{H}_2$  + Liq.  $\text{O}_2$
  - (b) Liq.  $\text{N}_2$  + Liq.  $\text{O}_2$
  - (c) Liq.  $\text{H}_2$  + Liq.  $\text{N}_2$
  - (d) Liq.  $\text{O}_2$  + Liq. air
- 10 Hydrogen exists in atomic state in which of the following compounds?
  - (a) Metallic hydrides
  - (b) Ionic hydrides
  - (c) Molecular hydrides
  - (d)  $\text{H}_2\text{O}$
- 11 Which of the following is electron precise hydride?
  - (a)  $\text{B}_2\text{H}_6$
  - (b)  $\text{NH}_3$
  - (c)  $\text{H}_2\text{O}$
  - (d)  $\text{CH}_4$
- 12 The hydrides of the first elements in groups 15-17 namely  $\text{NH}_3$ ,  $\text{H}_2\text{O}$  and HF respectively show abnormally high values for melting and boiling points. This is due to
  - (a) small size of N, O and F
  - (b) the ability to form extensive intermolecular H-bonding
  - (c) the ability to form extensive intramolecular H-bonding
  - (d) effective van der Waals' interaction
- 13 Ice floats on water because
  - (a) its density is less than that of water
  - (b) crystal structure of ice has empty space
  - (c) Both of the above
  - (d) None of the above
- 14 When zeolite, which is hydrated sodium aluminium silicate is treated with hard water, the sodium ions are exchanged with
  - (a)  $\text{H}^+$  ion
  - (b)  $\text{Ca}^{2+}$  ion
  - (c)  $\text{SO}_4^{2-}$  ion
  - (d)  $\text{OH}^-$  ion
- 15 Which one of the following statements about water is false? → JEE Main 2016
  - (a) Water can act both as an acid and as a base
  - (b) There is extensive intramolecular hydrogen bonding in the condensed phase
  - (c) Ice formed by heavy water sinks in normal water
  - (d) Water is oxidised to oxygen during photosynthesis
- 16 Which one of the following processes will produce hard water?
  - (a) Saturation of water with  $\text{CaSO}_4$
  - (b) Saturation of water with  $\text{CaCO}_3$
  - (c) Addition of  $\text{Na}_2\text{SO}_4$  to water
  - (d) Saturation of water with  $\text{MgCO}_3$
17. Which of the following is responsible for the permanent hardness of water?
  - (a) Calcium bicarbonate
  - (b) Sodium chloride
  - (c) Magnesium bicarbonate
  - (d) Calcium sulphate
18. Permutit is chemically
  - (a) hydrated sodium aluminium silicate
  - (b) sodium hexaphosphate
  - (c) sodium bicarbonate
  - (d) calcium hydroxide

**19.** The hardness of water sample containing 0.002 mole of magnesium sulphate dissolved in a litre of water is expressed as

- (a) 20 ppm (b) 200 ppm  
(c) 2000 ppm (d) 120 ppm

**20** Hydrogen peroxide is used as

- (a) an oxidant only (b) a reductant only  
(c) an acid only (d) All of these

**21** Decomposition of  $\text{H}_2\text{O}_2$  is favoured by

- (a) traces of acids (b) alcohol  
(c) acetanilide (d) MnO

**22** In aqueous solution, hydrogen peroxide oxidises  $\text{H}_2\text{S}$  to

- (a) sulphur (b) sulphuric acid  
(c) Caro's acid (d) Marshall's acid

**23** 30 volume hydrogen peroxide means

- (a) 30% of  $\text{H}_2\text{O}_2$  solution  
(b)  $30\text{cm}^3$  of the solution contains 1g of  $\text{H}_2\text{O}_2$   
(c)  $1\text{cm}^3$  of the solution liberates  $30\text{cm}^3$  of  $\text{O}_2$  at STP  
(d)  $30\text{cm}^3$  of the solution contains 1 mole of  $\text{H}_2\text{O}_2$

**24** Which of the following statements is not correct ?

- (a)  $\text{H}_2\text{O}_2$  oxidises Fe (II) to Fe (III)  
(b)  $\text{H}_2\text{O}_2$  can be obtained by electrolysis of dil.  $\text{H}_2\text{SO}_4$   
(c)  $\text{H}_2\text{O}_2$  reduces Mn (VII) to Mn (II)  
(d)  $\text{H}_2\text{O}_2$  is a weak base

**25** Acidified solution of chromic acid on treatment with  $\text{H}_2\text{O}_2$  yields

- (a)  $\text{CrO}_3 + \text{H}_2\text{O} + \text{O}_2$   
(b)  $\text{Cr}_2\text{O}_3 + \text{H}_2\text{O} + \text{O}_2$   
(c)  $\text{CrO}_5 + \text{H}_2\text{O} + \text{K}_2\text{SO}_4$   
(d)  $\text{H}_2\text{Cr}_2\text{O}_7 + \text{H}_2\text{O} + \text{O}_2$

**26** Hydrogen peroxide when added to a solution of potassium permanganate acidified with  $\text{H}_2\text{SO}_4$ ,

- (a) forms water only  
(b) acts as an oxidising agent  
(c) acts as a reducing agent  
(d) reduces sulphuric acid

**27** Consider the following reactions :

- I.  $\text{H}_2\text{O}_2 + \text{O}_3 \longrightarrow \text{H}_2\text{O} + 2\text{O}_2$   
II.  $\text{H}_2\text{O}_2 + \text{Ag}_2\text{O} \longrightarrow 2\text{Ag} + \text{H}_2\text{O} + \text{O}_2$

Role of hydrogen peroxide in the above reactions is respectively

- (a) oxidising in I and reducing in II  
(b) reducing in I and oxidising in II  
(c) reducing in I and II  
(d) oxidising in I and II

**28.** Hydrogen peroxide oxidises  $[\text{Fe}(\text{CN})_6]^{4-}$  to  $[\text{Fe}(\text{CN})_6]^{3-}$  in acidic medium but reduces  $[\text{Fe}(\text{CN})_6]^{3-}$  to  $[\text{Fe}(\text{CN})_6]^{4-}$  in alkaline medium. The other products formed are, respectively. → JEE Main 2015

- (a)  $(\text{H}_2\text{O} + \text{O}_2)$  and  $\text{H}_2\text{O}$   
(b)  $(\text{H}_2\text{O} + \text{O}_2)$  and  $(\text{H}_2\text{O} + \text{OH}^-)$   
(c)  $\text{H}_2\text{O}$  and  $(\text{H}_2\text{O} + \text{O}_2)$   
(d)  $\text{H}_2\text{O}$  and  $(\text{H}_2\text{O} + \text{OH}^-)$

**29.** From the following statements regarding  $\text{H}_2\text{O}_2$ , choose the incorrect statement. → JEE Main 2018

- (a) It can act only as an oxidising agent  
(b) It decomposed on exposure to light  
(c) It has to be stored in plastic or wax lined glass bottles in dark  
(d) It has to be kept away from dust

**Direction** (Q. Nos. 30-32) *In the following questions, Assertion (A) followed by a Reason (R) is given. Choose the correct answer out of the following choices.*

- (a) Assertion and Reason both are correct and Reason is the correct explanation of the Assertion  
(b) Assertion and Reason both are correct but Reason is not the correct explanation of the Assertion  
(c) Assertion is correct and Reason is incorrect  
(d) Both Assertion and Reason are incorrect

**30. Assertion** Density of ionic hydrides such as LiH is greater than that of metals from which they are formed.

**Reason** Small  $\text{H}^-$  (hydride ions) occupy holes in the lattice of metal without distorting metal lattice.

**31. Assertion** Melting point of  $\text{D}_2\text{O}$  is higher than that of  $\text{H}_2\text{O}$ .

**Reason** Heavy water is more viscous than ordinary water,  $\text{H}_2\text{O}$ .

**32. Assertion**  $\text{H}_2\text{O}_2$  acts as an oxidising agent as well as reducing agent.

**Reason** In  $\text{H}_2\text{O}_2$ , oxygen has  $-1$  oxidation state and it can increase or decrease its oxidation state.



## DAY PRACTICE SESSION 2

# PROGRESSIVE QUESTIONS EXERCISE

- 1 Out of LiH, MgH<sub>2</sub> and CuH
  - (a) all are ionic hydrides
  - (b) LiH, MgH<sub>2</sub> are ionic and CuH covalent hydride
  - (c) all are covalent hydrides
  - (d) LiH is ionic, MgH<sub>2</sub> and CuH are intermediate hydrides
- 2 The hydride ion H<sup>-</sup> is stronger base than its hydroxide ion OH<sup>-</sup>. Which of the following reactions will occur if sodium hydride (NaH) is dissolved in water?
  - (a)  $2\text{H}^+ (\text{aq}) \longrightarrow \text{H}_2 + 2\text{e}^-$
  - (b)  $\text{H}^- (\text{aq}) + \text{H}_2\text{O}(\text{l}) \longrightarrow \text{OH}^- + \text{H}_2$
  - (c)  $\text{H}^- + \text{H}_2\text{O}(\text{l}) \longrightarrow$  No reaction
  - (d) None of the above
- 3 The compound sodium polymeta phosphate Na<sub>2</sub>[Na<sub>4</sub>(PO<sub>3</sub>)<sub>6</sub>] is called Calgon because
  - (a) it was developed by the scientist
  - (b) it was developed first in California
  - (c) it refers to calcium gone
  - (d) it is based on the name of the company which developed
- 4 Which of the following statements concerning protium, deuterium and tritium is not true?
  - (a) They are isotopes of each other
  - (b) They have similar electronic configurations
  - (c) They exists in the nature in the ratio of 1 : 2 : 3 respectively
  - (d) Their mass numbers are in the ratio 1 : 2 : 3 respectively
- 5 Select the incorrect statement.
  - (a) *Ortho* and *para* hydrogen are different due to difference in their nuclear spins
  - (b) *Ortho* and *para* hydrogen are different due to different in their electron spins
  - (c) *Para* hydrogen has a lower internal energy than that of *ortho* hydrogen
  - (d) *Para* hydrogen is more stable at lower temperature
- 6 Which one of the following statements is incorrect with regard to *ortho* and *para* dihydrogen?
  - (a) They are nuclear spin isomers
  - (b) The *ortho* isomer has zero nuclear spin whereas the *para* isomer has one nuclear spin
  - (c) The *para* isomer is favoured at low temperatures
  - (d) The thermal conductivity of the *para* isomer is 50% greater than that of the *ortho* isomer
- 7 H<sub>2</sub> can be obtained from
  - (a) water gas (CO + H<sub>2</sub>) by liquefaction of CO at low temperature under pressure
  - (b) water gas by oxidation of CO into CO<sub>2</sub> (by steam) which can be easily removed by dissolving in H<sub>2</sub>O
  - (c) electrolysis of water
  - (d) All the above methods can be used to obtain H<sub>2</sub>
- 8 Which one of the following pairs of substances will not produce hydrogen when reacted together?
  - (a) Copper and conc. nitric acid
  - (b) Ethanol and metallic sodium
  - (c) Magnesium and steam
  - (d) Phenol and metallic sodium
- 9 Metal hydrides are ionic, covalent or molecular in nature. Among LiH, NaH, KH, RbH, CsH, the correct order of increasing ionic character is
  - (a) LiH > NaH > CsH > KH > RbH
  - (b) LiH < NaH < KH < RbH < CsH
  - (c) RbH > CsH > NaH > KH > LiH
  - (d) NaH > CsH > RbH > LiH > KH
- 10 Which of the following equations depicts the oxidising nature of H<sub>2</sub>O<sub>2</sub>?
  - (a)  $2\text{MnO}_4^- + 6\text{H}^+ + 5\text{H}_2\text{O}_2 \longrightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 5\text{O}_2$
  - (b)  $2\text{Fe}^{3+} + 2\text{H}^+ + \text{H}_2\text{O}_2 \longrightarrow 2\text{Fe}^{2+} + 2\text{H}_2\text{O} + \text{O}_2$
  - (c)  $2\text{I}^- + 2\text{H}^+ + \text{H}_2\text{O}_2 \longrightarrow \text{I}_2 + 2\text{H}_2\text{O}$
  - (d)  $\text{KIO}_4 + \text{H}_2\text{O}_2 \longrightarrow \text{KIO}_3 + \text{H}_2\text{O} + \text{O}_2$
- 11 Which of the following equation depicts reducing nature of H<sub>2</sub>O<sub>2</sub>?
  - (a)  $2[\text{Fe}(\text{CN})_6]^{4-} + 2\text{H}^+ + \text{H}_2\text{O}_2 \longrightarrow 2[\text{Fe}(\text{CN})_6]^{3-} + 2\text{H}_2\text{O}$
  - (b)  $\text{I}_2 + \text{H}_2\text{O}_2 + 2\text{OH}^- \longrightarrow 2\text{I}^- + 2\text{H}_2\text{O} + \text{O}_2$
  - (c)  $\text{Mn}^{2+} + \text{H}_2\text{O}_2 \longrightarrow \text{Mn}^{4+} + 2\text{OH}^-$
  - (d)  $\text{PbS} + 4\text{H}_2\text{O}_2 \longrightarrow \text{PbSO}_4 + 4\text{H}_2\text{O}$
- 12 Which one of the following statements is correct for H<sub>2</sub>O<sub>2</sub>?
  - (a) It reduces ferricyanide to ferrocyanide in acidic medium
  - (b) It oxidises lead monoxide to lead dioxide
  - (c) It acts as a reducing agent in the decolourisation of acidified KMnO<sub>4</sub>
  - (d) It oxidises hydrides of chlorine and bromine to their diatomic gases
- 13 Hydrogen resembles halogens in many respects for which several factors are responsible. Of the following factors which one is most important in this respect?
  - (a) Its tendency to lose an electron to form a cation
  - (b) Its tendency to gain a single electron in its valence shell to attain stable electronic configuration
  - (c) Its low negative electron enthalpy value
  - (d) Its small size

# ANSWERS

## SESSION 1

1 (c)	2 (b)	3 (c)	4 (a)	5 (a)	6 (d)	7 (a)	8 (d)	9 (a)	10 (a)
11 (d)	12 (b)	13 (c)	14 (b)	15 (b)	16 (a)	17 (d)	18 (a)	19 (b)	20 (d)
21 (d)	22 (a)	23 (c)	24 (d)	25 (c)	26 (c)	27 (a)	28 (c)	29 (a)	30 (a)
31 (b)	32 (a)								

## SESSION 2

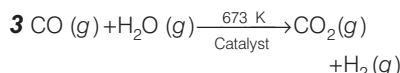
1 (d)	2 (b)	3 (c)	4 (c)	5 (b)	6 (b)	7 (d)	8 (a)	9 (b)	10 (c)
11 (b)	12 (c)	13 (b)							

# Hints and Explanations

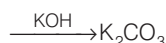
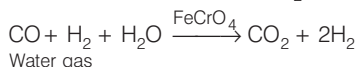
## SESSION 1

**1** *Ortho* and *para*-hydrogens differ in the nature of spins of protons.

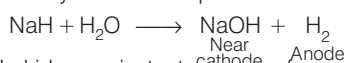
**2** Zn is amphoteric metal and reacts with acids as well as alkalis to give hydrogen gas.



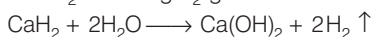
**4** In this reaction, CO is oxidised to CO<sub>2</sub> with steam in the pressure of catalyst followed by absorption of CO<sub>2</sub> in alkali.



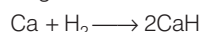
**5** H<sub>2</sub> gas is liberated at anode by electrolysis of NaH aqueous solution.



**6** Hydrides are instant sources of hydrogen of higher purity. They react with H<sub>2</sub>O forming H<sub>2</sub> gas.



**7** Calcium when reacts with hydrogen forms calcium hydride. Here, dihydrogen act as oxidising agent.



**8** In ice, each H<sub>2</sub>O molecule is surrounded tetrahedrally by four other water molecules through H-bonds.

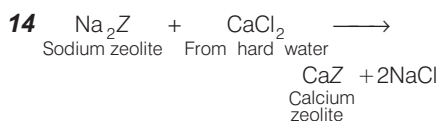
**9** Liquid H<sub>2</sub> and liquid O<sub>2</sub> are used as rocket propellants.

**10** Hydrogen exists in atomic state in metallic hydrides.

**11** The hydride which contains exact number of electrons to form normal covalent bonds are called electron precise hydrides, e.g. CH<sub>4</sub>.

**12** Hydrides of N, O and F because of the small size and high electronegativity of elements have ability to form extensive intermolecular, (i.e. between two molecules) hydrogen bonding. Thus, a large amount of energy is required to break these bonds, the melting and boiling points of hydrides of these elements are abnormally high.

**13** Ice floats on water because its density is less than that of water which in turn is due to empty space in its crystal structure. Crystal structure of ice is regular hexagon with empty spaces at the centre.



[where, Z = Al<sub>2</sub>Si<sub>2</sub>O<sub>8</sub> · x H<sub>2</sub>O]

**15** Water consists of extensive intermolecular H-bonding in the condensed phase.

**16** Permanent hardness is due to the presence of chlorides and sulphates of calcium, magnesium and iron in water.

**17** Chlorides and sulphates of calcium and magnesium are responsible for the permanent hardness of water. Hence, CaSO<sub>4</sub> is responsible for the permanent hardness of water.

**18** Permutit is chemically hydrated sodium aluminium silicate.

**19** The hardness of water sample containing 0.002 mole of MgSO<sub>4</sub> dissolved in 1 L of water.

Hardness is measured in terms of ppm of CaCO<sub>3</sub>.

$$\text{MgSO}_4 \equiv \text{CaCO}_3 \equiv 0.002 \text{ mol L}^{-1}$$

$$\text{CaCO}_3 = 0.002 \times 100 \text{ g L}^{-1}$$

$$= 0.002 \times 100 \text{ g in } 10^3 \text{ mL}$$

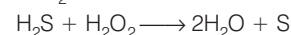
$$= \frac{0.002 \times 100 \times 10^6}{10^3} \text{ g in } 10^6 \text{ mL (ppm)}$$

$$= 200 \text{ ppm}$$

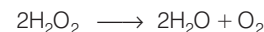
**20** H<sub>2</sub>O<sub>2</sub> acts as an oxidant, reductant and an acid (weak).

**21** MnO catalysis the decomposition of H<sub>2</sub>O<sub>2</sub>.

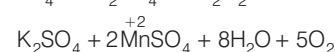
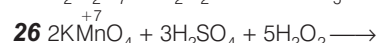
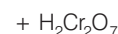
**22** In aqueous solution, hydrogen peroxide oxidises H<sub>2</sub>S to S.



**23** 30 Volume hydrogen peroxide means 1 cm<sup>3</sup> of this solution produces 30 cm<sup>3</sup> O<sub>2</sub> at NTP.



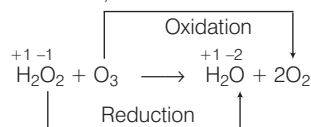
**24** H<sub>2</sub>O<sub>2</sub> is not a weak base but a weak acid.



∴ H<sub>2</sub>O<sub>2</sub> is acting as a reducing agent. It reduces KMnO<sub>4</sub> to Mn<sup>2+</sup> ion.

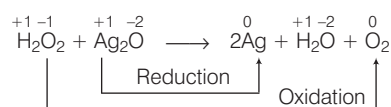


**27** In the reaction,



The oxidation state of oxygen in  $\text{H}_2\text{O}_2$  changes from  $-1$  to  $-2$ .  $\text{H}_2\text{O}_2$  oxidises  $\text{O}_3$  into  $\text{O}_2$ , thus it behaves as an oxidising agent.

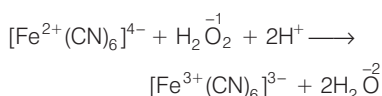
For the reaction,



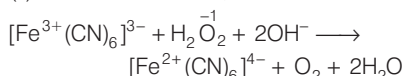
In the above reaction,  $\text{H}_2\text{O}_2$  reduces  $\text{Ag}_2\text{O}$  to  $\text{Ag}$  and the oxidation state of  $\text{O}$  changes from  $-1$  to  $0$ , hence it acts as a reducing agent.

**28** Both reactions in their complete format are written below

(i) In acidic medium,



(ii) In alkaline medium,



Hence,  $\text{H}_2\text{O}$  (for reaction (i)) and  $\text{O}_2 + \text{H}_2\text{O}$  (for reaction (ii)) are produced as by product.

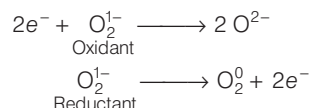
**29**  $\text{H}_2\text{O}_2$  acts as an oxidising as well as reducing agent, because oxidation number of oxygen in  $\text{H}_2\text{O}_2$  is  $-1$ . So, it can be oxidised to oxidation state  $0$  or reduced to oxidation state  $-2$ .

$\text{H}_2\text{O}_2$  decomposes on exposure to light. So, it has to be stored in plastic or wax lined glass bottles in dark for the prevention of exposure. It also has to be kept away from dust.

**30** Ionic hydrides are solid with high density because small  $\text{H}^-$  ion occupy holes in the lattice of metal without distorting metal lattice.

**31**  $\text{D}_2\text{O}$  shows more stronger H-bonding than  $\text{H}_2\text{O}$  and thus, shows higher melting and boiling points. Also, heavy water is more viscous than ordinary water.

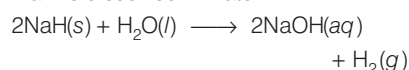
**32**  $\text{H}_2\text{O}_2$  acts as an oxidising as well as reducing agent because oxygen has  $-1$  oxidation state, so it can be oxidised to oxidation state  $0$  or reduced to oxidation state  $-2$ .



## SESSION 2

**1**  $\text{LiH}$  is ionic,  $\text{MgH}_2$  and  $\text{CuH}$  are intermediate hydrides.

**2** Following reactions take place when  $\text{NaH}$  is dissolved in water.



**3** The compound sodium polymetaphosphate  $\text{Na}_2[\text{Na}_4(\text{PO}_3)_6]$  is called calgon because it refers to calcium gone.

**4** Protium, deuterium and tritium exist in nature in the ratio of  $3 : 2 : 1$  respectively.

**5** *Ortho* and *para* hydrogen are different due to difference in proton spin and not electron spin.

**6** On the basis of spinning of protons, hydrogen has two allotropes, called *ortho* hydrogen and *para* hydrogen. In *ortho* hydrogen, spins of protons are in same direction, so the nuclear spin  $= \frac{1}{2} + \frac{1}{2} = 1$ . While in *para* hydrogen, spins of protons are in opposite direction, so the nuclear spin

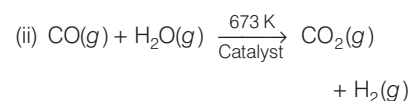
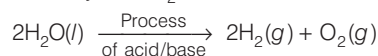
$$= \frac{1}{2} + \left(-\frac{1}{2}\right) = 0$$

All other statements about *ortho* and *para* hydrogens are true.

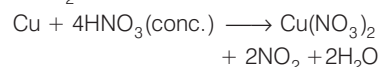
**7** Hydrogen can be obtained from water gas, i.e. by liquefaction of  $\text{CO}$  and by oxidation of  $\text{CO}$  into  $\text{CO}_2$ . It can also be obtained from electrolysis of water.

Reaction involved :

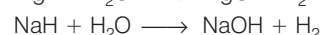
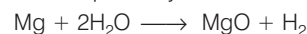
(i) Electrolysis of  $\text{H}_2\text{O}$



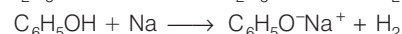
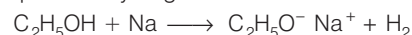
**8** Copper, being less reactive, when reacts with conc.  $\text{HNO}_3$ , gives  $\text{NO}_2$ , but not  $\text{H}_2$ .



While  $\text{Mg}$  and  $\text{NaH}$  being very reactive give hydrogen gas with steam and water respectively.



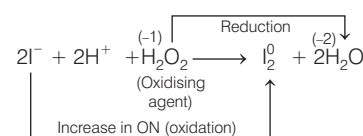
Ethanol and phenol due to the presence of acidic hydrogen also produce hydrogen with metallic sodium.



**9** Metal hydrides are ionic, covalent or molecular in nature. Ionic character increases as the size of the atom increases or the electronegativity of the atom decreases. The correct order of increasing ionic character is

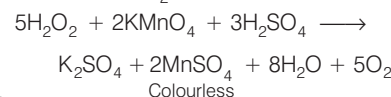


**10** The reaction in which  $\text{H}_2\text{O}_2$  is reduced, i.e. oxidation state of oxygen decreases from  $-1$  to  $-2$  depicts the oxidising nature of  $\text{H}_2\text{O}_2$ . e.g.



**11**  $\text{I}_2^0 + \text{H}_2\text{O}_2^{-1} + 2\text{OH}^- \longrightarrow 2\text{I}^- + 2\text{H}_2\text{O}^0 + \text{O}_2^0$  depicts reducing nature of  $\text{H}_2\text{O}_2$

**12**  $\text{H}_2\text{O}_2$  reduces acidified  $\text{KMnO}_4$  into colourless manganous salt and gets oxidised into  $\text{O}_2$ .



**13** Hydrogen resembles halogens in many respects for which several factors are responsible. The most important is hydrogen (like halogens) accepts an electron readily to achieve nearest inert gas configuration.